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Optimum utilization of renewable energy sources in a remote area

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Abstract

Energy is supplied in the form of electricity, heat or fuels and an energy supply system must guarantee sustainable energy supplies, production and distribution of energy. Such system based on renewable energy can be utilized as integrated renewable energy system (IRES), which can satisfy the energy needs of an area in appropriate and sustainable manner. For renewable energy based rural electrification of remote areas, the IRES can be modeled and optimized for meeting the energy needs. For the purpose, the Jaunpur block of Uttaranchal state of India has been selected as remote area. On the basis of field data, the resource potential and energy demand has been estimated. The total load is 808 MWh/yr and total available resources are 807 MWh/yr, whereas %age contribution of each resources are MHP 15.88% (128166), solar 2.77% (22363), wind 1.89% (15251) and biomass energy 79.46% (641384) kWh/yr. The model has been optimized using LINDO software 6.10 version. The results indicated that the optimized model has been found to the best choice for meeting the energy needs of the area. Renewable energy sources can contribute to the total energy demands as 16.81% (115465), solar 2.27% (15588), wind 1.78% (12201) and biomass energy 79.14% (543546) kWh/yr for the fulfillment of 687 MWh/yr at the 15% reduced level of 808 MWh/yr load. The results further indicated that optimized IRES can provide a feasible solution in terms of energy fulfillments in the range of EPDF from 1.0 to 0.75 because below 0.75 EPDF (0.50–0.25) the deficit start and so that model becomes non-feasible solution. The EPDF is electric power delivery factor and also called optimizing power factor and is maximum equal to 1. The paper reports the results of optimization of IRES models of the study area of Zone 4 of Jaunpur block of Uttaranchal state.

Keywords: Renewable energy; IRES modelling; Optimization; EPDF

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Contents

1. Introduction

The increasing consumption of conventional fuels coupled with environmental degradation has led to the development of eco-friendly renewable energy sources. The development of remote rural areas could not take place even after more than 50 years independence, as the grid could not be extended due to its high cost, scattered nature of the area and low load factor. In recent years, the considerable R&D has been initiated to energize such areas through renewable energy sources, which are the best candidate for supplying the energy in decentralized mode. Depending upon the topography of the area, energy resources potential available, and type of energy needs/demand and socioeconomic status of remote areas, the energy models can be developed and optimized in order to suit the needs of the area. Apart from meeting the energy needs using energy resources in individualistic manner, the demand can be best met using combination of the resources in integrative manner in cost effective and sustainable manner. The present study confines to electrical energy needs only. The aim of integrated renewable energy system (IRES) design is to pros of some energy sources with the cones of the other technologies. A reserve capacity is always necessary to act as a back up to overcome fluctuations in the electricity demand and supplies.

The paper reports the literature review, features of study area, assessment of resources and the demand of energy, development of models, optimization and selection of appropriate model suitable for the area.

2. Literature review

The concept based on an appropriate combination of solar, wind and biomass systems was used by [1] who proved that IRES is reliable and viable concept from energy production and utilization point of view. Further, the small-scale decentralized IRES concepts were discussed by [2] who considered SPV, solar thermal, wind, biomass and falling water as renewable resources. A methodology was also developed by [3] to design IRES using a linear programming (LP) approach, which minimizes an objective function of total annual cost, subject to a set of energy and power constraints. A mathematical approach has been used in a simple and useful form and is directly applicable for the

design of stand-alone IRES for rural area of developing countries. [4] focused on the design of stand-alone IRES with the technical and economic aspects and utilized loss of power supply probability (LPSP) as the key system variable. Some typical design scenarios were evolved by [5] using the knowledge-based design tool IRES-KB with the aid of KAPP$^{(R)}$-PC development tools. A remote village with no electrical grid was chosen in the developing countries and the versatility of IRES-KB was proved. [6] further found that IRES can play significant role in meeting the energy need of a rural areas and to improving the living conditions of the people. He observed that the concept of energization through resource-need matching has been found to be preferable as compared to straightforward rural electrification. An optimal renewable energy model (OREM) was developed by [7], which minimized the cost/efficiency ratio with the social acceptance, resource limitation, and demand and reliability factors used as constraints. About 38 different renewable energy options are considered in the model. [8] developed a micromodel for designing a rural energy supply system considering lighting, cooking and irrigation as end use applications. A model was developed by [9] using Grey LP model and hourly loads and the hourly inflows expressed in Grey number notation, in order to reach an optimal scheduling under certain environment. A LP based energy model was developed by [10] to minimize the output of agricultural residue (biomass) by suitably allocating the land area for cultivation of various crops in a taluka of South India. The model optimized the surplus biomass production using the available resource such as human, animal, tractor power, fertilizer and pesticides subject to the fulfillment of the food requirements of the taluka with regard to cereals, pulses, oilseeds, sugar, vegetables, fuel as well as animal fodder. Further, authors estimated the power potential from surplus biomass and matched the energy demand with the supply. It has been calculated the quantity of power that can be generated through biomass combustion process on the basis of 1.5 tons of agro-residue is equal to 1 MW h of electrical energy. A computer software package HYPER-LINPO using AT 486-DX2 Computer System was used to estimate the surplus biomass. The authors recommended the model for integrated energy planning at taluka level. [11] was a member of the Air Force group, formulated the general linear programming problem and devised the Simplex Method of solution in 1947. GMP was developed by [12]. [13] extended the method so as to be applicable to problems in which some of the terms in the objective and constraint functions may have negative coefficients. [14] developed a procedure for converting integer polynomial programming to zero-one Linear Programming problems. DP technique was developed by [15,16] in the early 1950s. [17] developed stochastic programming techniques and solved problems by assuming design parameters to be independent and normally distributed. The quadratic programming procedure was developed by [18] to apply phase I of simplex method.

The literature revels that very little work has been reported on integration of MHP with other sources. Since the study area, being hilly terrain, is reach in hydro resources, it was considered worthwhile to develop and optimize IRES models consisting of MHP, biomass, solar and wind energy for the purpose of providing electricity to the study area.

3. Features of study area

Uttaranchal was created as new state in the year 2000 and consists of 13 districts, out of which Tehri Garhwal has been selected as the district of the study area as it comprises of

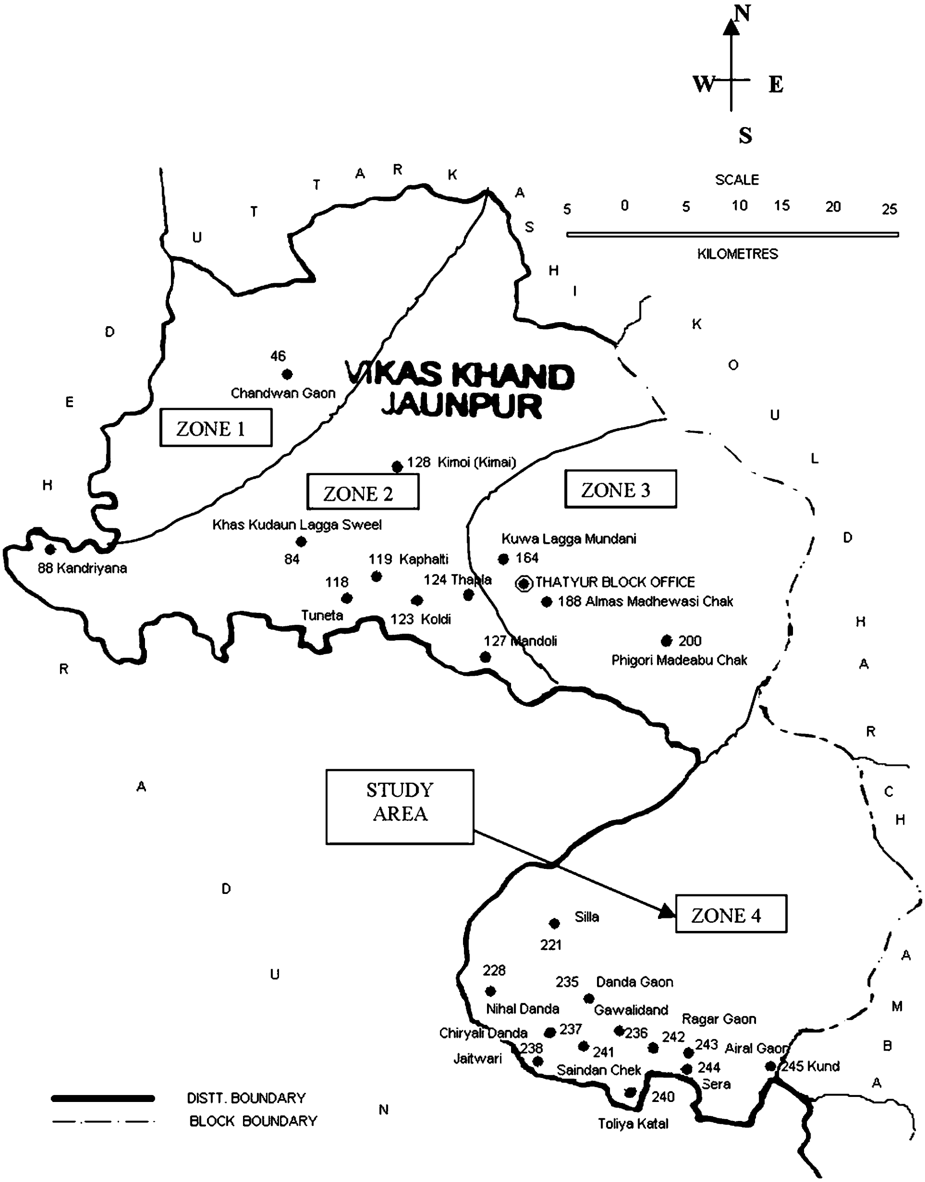

Fig. 1. Map of un-electrified villages (Uttaranchal state, district-Tehri Garhwal, Jaunpur block).

major hilly and the fertile area under forest. The district is surrounded by UttarKashi in the north, Dehradun in the west, Pauri Garhwal in the south and Rudraprayag in the east as shown in Fig. 1. The area has a total area of 485 km^2 and total population 50,636. The total numbers of villages are 259 with 202 electrified and 57 un-electrified villages. The electrification of 24 villages has been taken under by Uttaranchal Renewable Energy Development Agency) (UREDA) using biomass followed by hydro resources.

Table 1
Data of Jaunpur block

Sl no.	Items	Total
1	No. of villages	259
2	No. of un-electrified villages (by UREDA)	24
3	No. of water mills (Gharat) installed	52
4	No. of springs available	30
5	No. of falls available	8
6	No. of reserved forest (RF)	22

Table 2
General features of study area (Jaunpur block)

Features	Uttaranchal	Zone 1	Zone 2	Zone 3	Zone 4
Total population	8,479,562	13,845	7574	19369	9848
Income group	LIG/MIG/HIG	HIG	MIG	MIG	LIG
Geology	28.47–31.20 N, 77.35–80.55 E	30.04–30.34 N, 78.03–78.14 E	30.04–30.34 N, 78.03–78.14 E	30.04–30.34 N, 78.03–78.14 E	30.04–30.34 N, 78.03–78.14 E
Un-electrified villages	1127 out of 16, 414 villages (7%)	01	08	03	12
Economic	Economically weak state	Economically poor zone	Economically very poor zone	Economically most backward and weaker zone	Economically most-most poorest and weakest zone
Social	Socially poor state	(i) Lack of education (ii) Lack of communication (iii) Lack of water supply (iv) Backward area	(i) Lack of welfare center (ii) Literacy rate very poor (iii) Lack of communication (iv) Most backward area	(i) Lack of education (ii) Near Dehradun area (iii) No any type of road (iv) Backward area and remote area	(i) Lack of education (ii) No medical facility (iii) No any type of road (iv) Most backward and remote area

As per Table 1, the Jaunpur block (study area) divided in to four zones and only 9% of the total villages are un-electrified, which have been considered for the present study as the best candidate for electrification by decentralized IRES systems consisting of biomass, MHP, solar and wind energy resources. Head quarter is located in New Tehri. Out of 10 blocks (Vikas Khand), the block Jaunpur was selected as remote area for the present study. Table 2 depicts the main features of the area, which shows that 0.16% population is high, 0.32% middle, and 0.12% low-income group people. The later has been observed to be economically poorest and weakest and lack enough for employment opportunities, have very poor purchasing power and are totally dependent upon natural forest for their energy and material demands. A total of 24 un-electrified remote villages have been considered to be electrified by renewable electricity. This will enable the people to set-up small-scale

industries and raise their living standards. However, the present study will focus only on the energization of 12 villages of Zone 4 through of IRES system.

3.1. Assessment of energy potential and energy demand

The energy resources data as given in Table 3 shows that the biomass constitutes maximum potential (641 MW h/yr) followed by micro-hydro (128 MW h/yr), solar (22 MW h/m^2/yr) and wind energy (15 MWh/m^2/yr). Though the actual exploitation of potential will depend upon the system configuration, its cost in terms of cost of energy is delivered. The data also shows that the total potential including all the resources considered is about 807 MW h/yr while the total demand are 808 MW h/yr. This means that the energy demands of the area can be fully met by fully exploiting the available resources. Therefore, the entire electricity generation will be 807 MW h/yr and accordingly the model consisting of MHP, BES (Gasifier system only), SPV, and WES has been considered. The unit energy costs have been calculated using standard procedures described by [19] and is based on Capital cost of Installed capacity, O&M costs, life of plants, etc. used for calculation for each resource. The results as reported in Table 4 show that the unit cost of energy from different resources has been found as 1.50 from MHP, 3.10 from biomass, 3.00 from wind and Rs 15.27 per unit from SPV.

The energy needs of the area have been identified as domestic, agricultural, transportation and motive power for small-scale industries. The energy demands in different sectors calculated on the basis of data collected are given in Table 5, which shows that the total demand is lower than energy production after considering 15% of the reduced demand. The load demand has therefore been reduced for the proper fulfillment of the load, which allows the model to function, failing which the model can not function under the condition when load becomes more than the resource. The available resources considered above may therefore be able to satisfy about 85% of the demand, 687 MW h/yr.

4. Modelling of IRES system

The challenge in designing a reliable renewable energy system is to find a combination of technologies where the pros of some types balanced out the cons of the others. A reserve capacity is necessary as a backup for fluctuating sources, especially in the electrical system. Designing a combination of renewable technologies where fluctuations in production match a varying demand, such that any fluctuations in supply never lead to electrical production that cannot meet the demand, can minimize this capacity. The model requires the assessment of the energy share of each of the supply inputs with the objective of achieving a minimum cost of energy generation.

An integrated energy model has been constructed for the major end uses lighting mainly and other uses also. The general model can be formulated on basis of LP as

$$\begin{aligned} \text{Minimize :} \quad & Z_{\mathrm{T}} = \sum C_1 ij \times Xij \\ \text{Subject to :} \quad & \sum X_{ij} = D_j \\ & \sum X_{ij}/\eta_{ij} \leqslant S_i \\ & X_{ij} \geqslant 0 \end{aligned}$$

Table 3
Data of 12-un-electrified villages of ZONE 4

Sl no.	Village name	Tehsil	Area (km^2)	House holds	Population	Total load (kW h/yr)	Resources				Total resource (kW h/yr)
							Microhydro (kW h/yr)	Solar (kW h/m^2/yr)	Wind (kW h/m^2/yr)	Biomass (kW h/yr)	
1	Silla	TEHRI	98.37	40	188	118,856	2851	1863	1270	13,508	19,492
2	Nihaldanda	TEHRI	11.84	7	35	18,455	NA	1863	1270	1805	4938
3	Dandagaon	TEHRI	42.23	7	40	16,252	NA	1863	1270	2118	5251
4	Gawalidanda	TEHRI	87.5	6	50	19,164	NA	1863	1270	1529	4662
5	Chifalti (Chiryali Danda)	TEHRI	26.79	8	50	20,405	1369	1863	1270	2623	7125
6	Jaintwari	TEHRI	48.65	10	70	29,071	NA	1863	1270	3139	6272
7	Talyakatal	TEHRI	61.41	14	75	34,879	NA	1863	1270	3958	7091
8	Sandna laga Gawali Danda	TEHRI	14.33	14	100	43,234	15,263	1863	1270	23,142	41,538
9	Ragargaon	TEHRI	123.42	45	225	224,441	73,715	1863	1270	508,807	585,655
10	Airalgaon	TEHRI	97.36	15	120	43,696	NA	1863	1270	5883	9016
11	Sera	TEHRI	51.03	40	300	111,445	8672	1863	1270	51,826	63,631
12	Kund	TEHRI	175.36	35	150	127,746	26,295	1863	1270	23,043	52,471
Total				241	1403	807,646	128,166	22,363	15,251	641,384	807,164

NA, not available. Total load required in the study area is 807,646 kW h/yr or 808 MW h/yr. Total resource available in the study area is 807,164 kW h/yr or 807 MW h/yr.

Table 4
Cost of energy (COE)

Resources (systems)	Cost function notation	Installed capacity (kW)	Potential/ annum (kW h)	Installed (capital) cost/kW (Rs)	Estimated annual capacity factor (k)	O&M cost (Rs/ kW h)	Useful life (yrs)	Per unit cost (Rs/kW h)
SPV	CF_{SPV}	2	1863	300,000–350,000	0.15 (0.2)*	1.125	20	15.27
MHP	CF_{MHP}	19.26	128,166	125,000	(0.76)*	0.3425	25	1.50
BES (biomass gasifier engine system)	CF_{BES}	70	641,384	230,000–275,000	0.9 (0.938)*	1.1458	20	3.10
WES	CF_{WES}	3	1270	45,000–70,000	0.24–0.4 (0.2)*	0.0959	20	3.5

Generally k ranges from 0.1 to 1 and ( )* indicates calculated values of k.

Table 5
Total electricity consumption/demand

Energy consumption sector	Energy demand (MW h/yr)
Domestic	781
Motive/industries	27
Agriculture	0.134
Transportation	0
Total demand	808
15% Reduced demand	687

where Z_T is the total cost of providing energy for all end uses for operation of the system; C_{ij}, cost/unit of the ith resource option for jth end use (Rs/kW h); Xij, optimal amount of ith resource option for jth end use (kWh); Dj, total energy for jth end use (kW h); S_i, availability of ith resource option for jth end use (kW h); η_{ij}, conversion efficiency for ith resource option for jth end use.

The final model can be formulated as:

$$
\begin{aligned}
\text{Minimize}: \quad & Z = 1.50\text{MHP} + 15.27\text{SPV} + 3.50\text{WES} + 3.10\text{BES} \\
\text{Subject to}: \quad & \text{MHP} + \text{SPV} + \text{WES} + \text{BES} = \text{D}\,\text{kW h/yr} \\
& \frac{\text{MHP}}{0.9} \leqslant 128,166\,\text{kW h/m}^2/\text{yr} \\
& \frac{\text{SPV}}{0.9} \leqslant 22,363\,\text{kW h/m}^2/\text{yr} \\
& \frac{\text{WES}}{0.80} \leqslant 15,251\,\text{kW h/m}^2/\text{yr} \\
& \frac{\text{BES}}{0.85} \leqslant 641,385\,\text{kW h/m}^2/\text{yr} \\
& \text{MHP}, \text{SPV}, \text{WES}, \text{BES} \geqslant 0
\end{aligned}
$$

where D (= 686,800 kW h/yr or 687 MW h/yr) is demand for model.

The above model shows that about 94% (641) of the total demand (687 MW h/yr) can be meet from biomass alone using gasifier engine system of suitable capacities, there by indicating that the selected area is very rich in biomass resource which could be the major source for energization of the area in future. Further, MHP has been found to provide about 19% (128) of the total demand. This may open new avenues for the exploitation of the hydro resources in the state. The other two sources like SPV and wind have marginal contribution, i.e. 3% (22) and 2% (15 MW h/yr), respectively. The present model has been adopted in order to make best use of the potential of the above sources, so that minimum cost of energy generation can be arrived from integration of all the sources as against the fact that the cost of energy is variable such as Rs 15.27 in the case of SPV, Rs 3.50 for wind, Rs 3.10 from biomass gasifier engine and Rs 1.50 per unit from MHP on the individual resource basis.

5. Optimization of IRES models

Various optimization techniques for Integrated Renewable Energy Sources have been reported in the literature like: (i) linear programming (LP) [11]; (ii) geometric programming

(GMP) [12,13]; (iii) integer programming (IP) [14]; (iv) dynamic programming (DP) [15,16]; (v) stochastic programming (St P) (Dantzig and Charnes and Cooper (1955, 1959)]; (vi) quadratic programming (QP) [18]; (vii) separable programming (Se P); (viii) multi-objective programming (MOP); (ix) goal programming (GP); (x) HOMER; (xi) VIPOR; and (xii) Hybrid 2, etc.

Presently, the softwares available for optimization are LINDO, LINDO API, LINGO, HOMER, VIPOR, TORA, etc., out of which LINDO software 6.10 version [22] has been reported to be the most traditional package for solving linear, integer and quadratic optimization models. The software offers the most comprehensive tools for studying the inner workings of the revised Simplex Method used to solve linear optimization models [21]. Its unique features are its goal programming, parametric analysis and efficient solution of quadratic programs. The software has been used as per the flow chart given in Fig. 2. To account for the reduction in the total energy delivered by the MHP/SPV/BES/WES, a term known as effective power delivery factor (EPDF) has been introduced, which may defined as the ratio of power obtained per season (or year) to the maximum power available per season (or year) [22].

$$\mathrm{EPDF} = \frac{\text{Power obtained/season (or year)}}{\text{Maximum power available/season (or year)}}$$

The epdf is normally used to improve life-cycle costs of the system, save power, save energy costs and reduce losses and is also sometimes called optimizing power factor.

6. Results and discussion

The results of optimization of the model using LINDO software 6.1 Version are given in Table 6 and graphically represented in Figs. 3–5, which indicate that at an EPDF of 1.0, the plants deliver the maximum energy to the load. Similarly, an EPDF of 0.75 gives 25% reduction in the energy delivery capability of the plant. In the present model, it is felt also that the breakdown/non-functioning of any one of renewable sources may drastically affect the overall system energy delivery capability.

The above results show the varying effect of EPDF on load shared by MHP, SPV, BES, and WES sources. At EPDF 1.0, MHP, SPV, WES, and BES fulfill the total load. Under this condition, the unit cost of energy of Rs 3.11/kW h is obtained. A reduction of EPDF from 1.0 to 0.25 indicates that all the four systems can meet the load at proportionally reduced level, against a total demand of 687 MW h/yr. With decrease in EPDF from 1.0 to 0.75, the cost of generation increases while a further reduction of EPDF leads to decrease in cost of energy and hence the energy deficit increases.

Further, the above results indicate that the present model of IRES can be feasibly utilized for energization of the study area between the EPDF values of 1.0 and 0.75. The model becomes unfeasible because of the increase in the energy deficit beyond EPDF of 0.75 and load is not properly fulfilled. It is clear from Table 6 that with decrease in EPDF there is an increase in the energy needs from MHP, though the constraints is of limited potential available which cannot be increased and therefore only MHP cannot be used to meet all the demand. Further, the potential from SPV also decreases even though the potential available is much more but the higher cost of the SPV system renders its use very limited. In the case of wind energy, the available potential is not harnessed due to the poor wind speeds available in the area thus making the use of the systems very uneconomical.

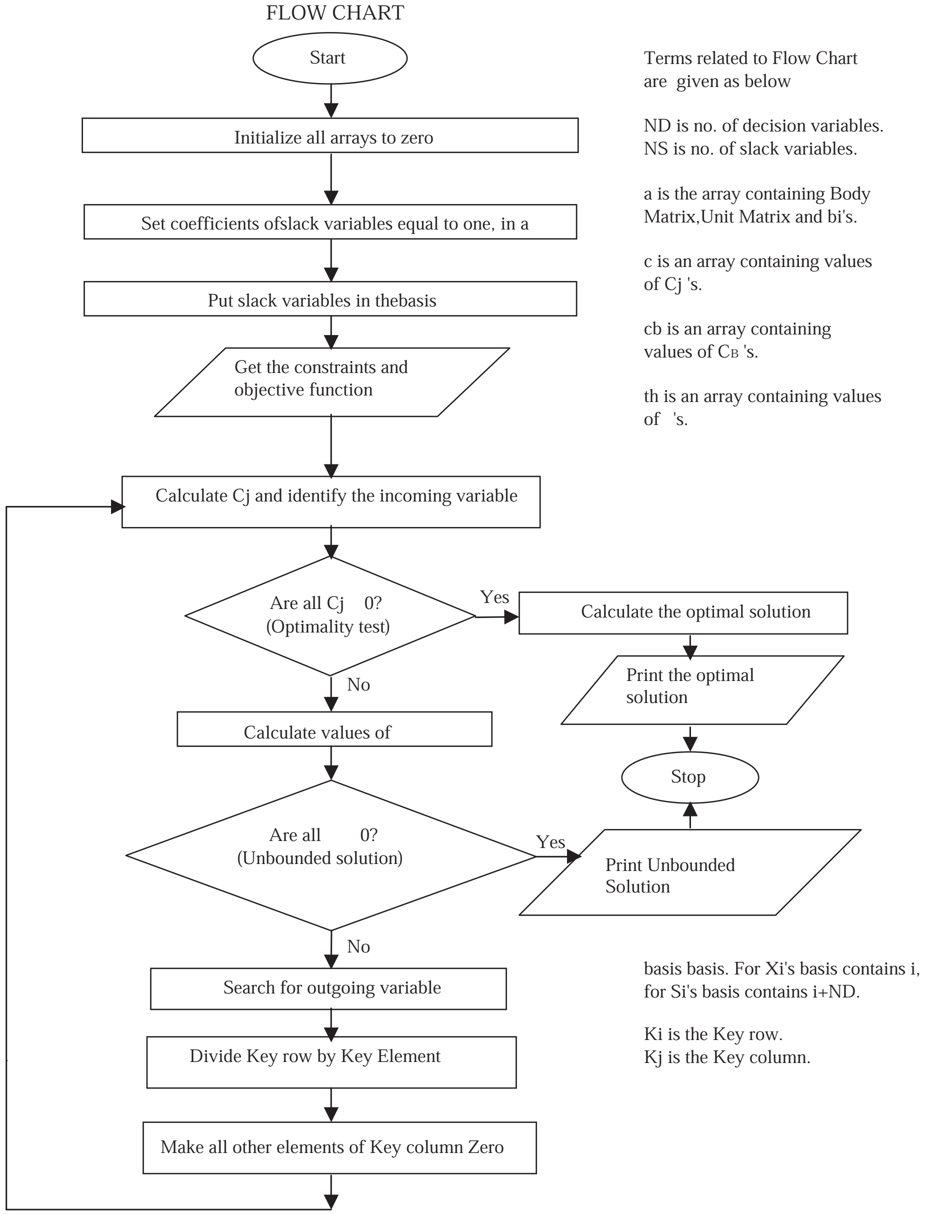

Fig. 2. Flow chart for model optimization.

Regarding the biomass energy it is clear that from EPDF 1.0 to 0.25 there is continuous decrease in the energy generation while the potential is too much. In order to fully utilize the biomass resource, one is required to explore the possibility of generating electricity using biomass gasifier engine system in decentralized mode because the cost of generation from the individual source is Rs 3.10, which fully matches with the cost of energy from the IRES system (Rs 3.11 per unit cost). Therefore, it may be concluded that depending upon

Table 6
Optimization results

Sl no.	EPDF	Objective function/ optimal cost (Rs)	MHP (kW h)	SPV (kW h)	WES (kW h)	BES (kW h)	Energy deficit (kW h)	Unit cost (Rs/ kW h)	Change in unit cost (%)
1	1.00	2,134,710	115,465	15,588	12,201	543,546	0	3.11	0
2	0.75	4,176,533	86,599	183,391	9151	407,660	186,792	6.08	49
3	0.5	1,613,229	398,853	10,073	6100	271,773	378,644	2.35	−32
4	0.35	1,438,320	485,237	7051	4270	190,241	493,755	2.09	−48
5	0.25	1,321,715	542,826	5037	3050	135,886	570,496	1.92	−62

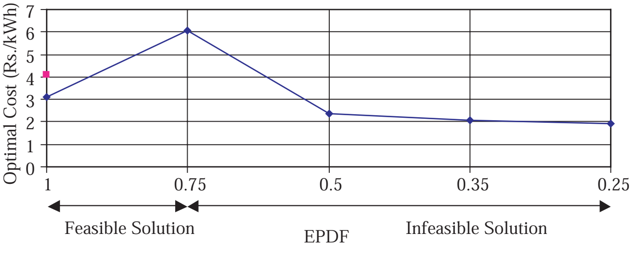

Fig. 3. Variation of optimal cost with EPDF for energy model.

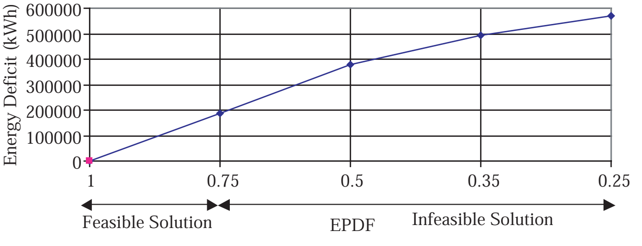

Fig. 4. Variation of energy deficit with EPDF for energy model.

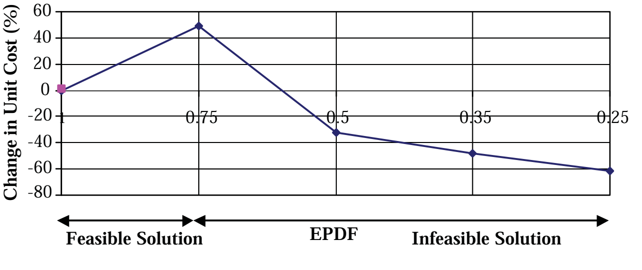

Fig. 5. Variation of change in unit cost with EPDF for energy model.

the distribution of the resource in the given area either a suitably designed and optimized IRES system or a biomass based gasifier engine system can be suitably used for the study area.

Based upon the above results, Figs. 3–5 give the variations of different values of EPDF with respect to the optimal cost of the system, energy deficit and the change in the unit cost, respectively. The values of EPDF for feasible solutions can be obtained by optimization.

7. Result verification

The results of optimization of the model using TORA software Version 1.00 are given in Table 7, which indicate that at an EPDF of 1.0, the plants deliver the maximum energy to the load. The result shows that the cost of energy of IRES is Rs 3.11 per unit, which is also similar to LINDO software's results.

7.1. Comparison of results between LINDO software and HOMER software

LINDO Software results. Different types of renewable energy model have been used in LINDO software for the determination of minimum cost of energy (COE) after the integration of the models. Such type of models are Summer Model (Lighting and Cooking), Winter Model (Lighting and Cooking), Domestic Model for Fan, TV, etc. application, Agriculture Model for irrigation and Motive/Industry Model for small-scale industry purposes. Among these models, the cost of energy has been obtained, which is different in each type of the model with the condition of feasible solution only, which is given in Table 8.

HOMER Software results. In HOMER analysis, mainly two types of models or hybrid systems have been obtained after the application of HOMER software in categorized mode in the case study. One is MHP–WES–BES hybrid system and another is MHP–SPV–WES–BES hybrid systems. Among these models or hybrid systems, different cost of energy has been obtained, which is shown in Table 9.

Therefore, using LINDO software cost of energy of the models ranges from Rs/kW h 1.47 to 3.50, whereas using HOMER software cost of energy of the models or hybrid systems ranges from Rs/kW h 4.10 to 4.15, which are very similar results and applicable for the study area. Further, the range of cost of energy from HOMER software is higher than the LINDO software, because in HOMER software cost of converter, local grid cost and batteries cost are included, whereas in LINDO software only renewable energy system's cost are involved.

Table 7
Optimization results

Sl no.	EPDF	Objective function/ optimal cost (Rs)	MHP (kW h)	SPV (kW h)	WES (kW h)	BES (kW h)	Energy deficit (kW h)	Unit cost (Rs/ kW h)	Change in unit cost (%)
1	1.00	2,138,919	115,465	15,588	12,201	543,546	0	3.11	0

Table 8
Models and COE

Sl no.	Models	COE (Rs/kW h)
1	Summer lighting	2.046
2	Winter lighting	2.046
3	Summer cooking	2.12
4	Winter cooking	2.174
5	Domestic	1.47
6	Agriculture	3.50
7	Motive/industry	1.47

Table 9
Models (or hybrid systems) and COE

Sl no.	Models or hybrid systems	COE (Rs/kW h)
1	MHP–WES–BES	4.10
2	MHP–SPV–WES–BES	4.15

8. Conclusion

In view of the worldwide energy shortages and environmental impacts of fossil fuel used, the concept of IRES has been considered for the typical Indian remote area, i.e. 12-un-electrified villages of Zone 4 of Jaunpur block, district Tehri Garhwal of Uttaranchal state for the meeting their energy needs. The unit cost of energy from each resource has been calculated on the basis of available resources and the demand of the area surveyed. An IRES model consisting of MHP, SPV, WES, and BES has been constructed and optimized using LINDO software 6.10 version. The results indicate that model can provide feasible solution only with EPDF 1.0–0.75 and beyond this it becomes unfeasible. The results further indicate that for the above area, either an IRES consisting of the above sources or a biomass gasifier engine system alone can provide a feasible solution in terms of energy fulfillments in the range of EPDF from 1.0 to 0.75. The results are verified using TORA software version 1.00. The comparative results are also shown between LINDO as well as HOMER software. The feasibility study shows that the IRES are most suitable and applicable system for any remote rural area.

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